

An Integrated Transportation-land Use Model For Indiana

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Abstract

Despite the recent research interest in integrating land use and transportation models inspired by federal legislation, no product had met the data, budget, and personnel constraints faced by the metropolitan planning organizations in Indiana. Consequently, the Indiana Department of Transportation sponsored a study to determine the feasibility of assembling a software package that would capture the relationships between land use and transportation that MPOs need to incorporate in their planning and analysis, while accounting for the current and expected status of Indiana MPO hardware and software capabilities. An Integrated Transportation Land Use Modeling System (ITLUMS) was developed by adapting standard land use models in the literature to the needs of Indiana MPOs. In addition, ITLUMS automates procedures that have been done manually and offers some new methods for key steps in the modeling process. ITLUMS was developed with the close participation of an MPO, whose data were used to calibrate, validate, and test the system. The results were satisfactory enough to justify proceeding to the implementation stage of the project.

The application of land-use/transportation models has evolved over two decades. The Clean Air Act Amendments (CAAA) of 1990 and the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 have accelerated this evolution. The CAAA demands that air quality forecasting must consider the interaction between land use and transportation and requires regional land use policies for mitigating congestion and environment impacts. The ISTEA requires long range transportation plans to quantify impacts on land use. For example, MPOs in non-attainment areas need to indicate whether new transport projects will have negative impacts on air quality.

Background

Land use planning in Indiana has been primarily a manual process. Planners at most of the MPOs in the state have met with key groups and individuals in their community. These participants typically generate several growth scenarios, then pool their experience, expertise, and judgment to determine likely future land use patterns by consensus. Software packages that perform some or most of this land use forecasting and allocation process are out of reach of most MPOs in Indiana. This is so for the following reasons:

- *Expense.* Many of the MPOs in Indiana are just beginning to acquire the hardware and software needed to install geographic information systems (GIS). The substantial additional cost of the more well-known land use models is not compatible with the budgets of most Indiana MPOs.
- *Black boxes.* Many of the land use models are run by their developers, who produce an answer or set of answers for the MPO/customer. MPOs would prefer to have control of software, whose constituent algorithms and processes they understand.¹
- *Data hungry.* Even if the previous two problems are overcome or neglected, many land use models require data that exceeds the amount of data routinely collected by Indiana MPOs or does not match the type of data they collect. Is it safe to assume that models built on data such

as “basic” and “non-basic” employment can be used with employment data categorized as retail and non-retail?

Research questions

In response to the issues raised in the previous section, the Indiana Department of Transportation (INDOT) commissioned researchers at Purdue University to investigate the feasibility of making available to the MPOs in Indiana a land use allocation model suitable for their needs. The subsequent research project had as its basic initial focus three important questions:

1. Can the land use allocation processes currently used by Indiana MPOs — or acceptable alternatives — be automated?
2. Can land use and transportation planning models be integrated into a process that is compatible?
3. Is the resulting process affordable - in terms of hardware, software, data, and personnel effort?

The research was guided by certain constraints. (1) The literature search was conducted with an awareness of what data were available to MPOs, or could be acquired by them with reasonable effort. (2) Any software developed to implement an integrated model ought to be compatible with the travel demand modeling package TRANPLAN. INDOT had acquired a statewide license for TRANPLAN and made it available to all the MPOs in the state. (3) Although few MPOs had an active GIS capability as the research started, INDOT was beginning to use GIS and certain low-price GIS packages were becoming available. Could the integrated model be implemented with a low-price GIS package?

Major ITLUMS Components

Because its objective was to assemble an easy-to-use package that would integrate standard land use allocation and travel demand models, the study began with a search through the literature for elements that would meet the specific needs and limitations of Indiana MPOs. The result of the study was the Integrated Transportation Land Use Modeling System (ITLUMS) illustrated in Figure 1. ITLUMS consists of three main components:

1. *A Land Use Allocation Module.* This module is based on a Lowry-Garin Gravity Model. It includes residential and employment location models in the Lowry-Garin tradition, but begins with two land use potential study techniques (described below) and employs a microeconomic-based land consumption model. It was also found to be both convenient and efficient to accomplish the trip generation and trip distribution steps of the travel demand analysis for home-based work and shopping trip within this module.
2. *A Travel Demand Module.* This module uses TRANPLAN to accomplish trip generation and trip distribution for the trip types not addressed in the Land Use Allocation Module. It also completes the remaining steps in the standard four-step transportation modeling process.

1. The authors of this paper confess to having their primary backgrounds in transportation planning. After hearing them make their “black box” remark in Dearborn, a subsequent speaker — whose primary expertise was in land use modelling — said that travel demand models could also be accused of being “black boxes.” The authors acknowledge this riposte.

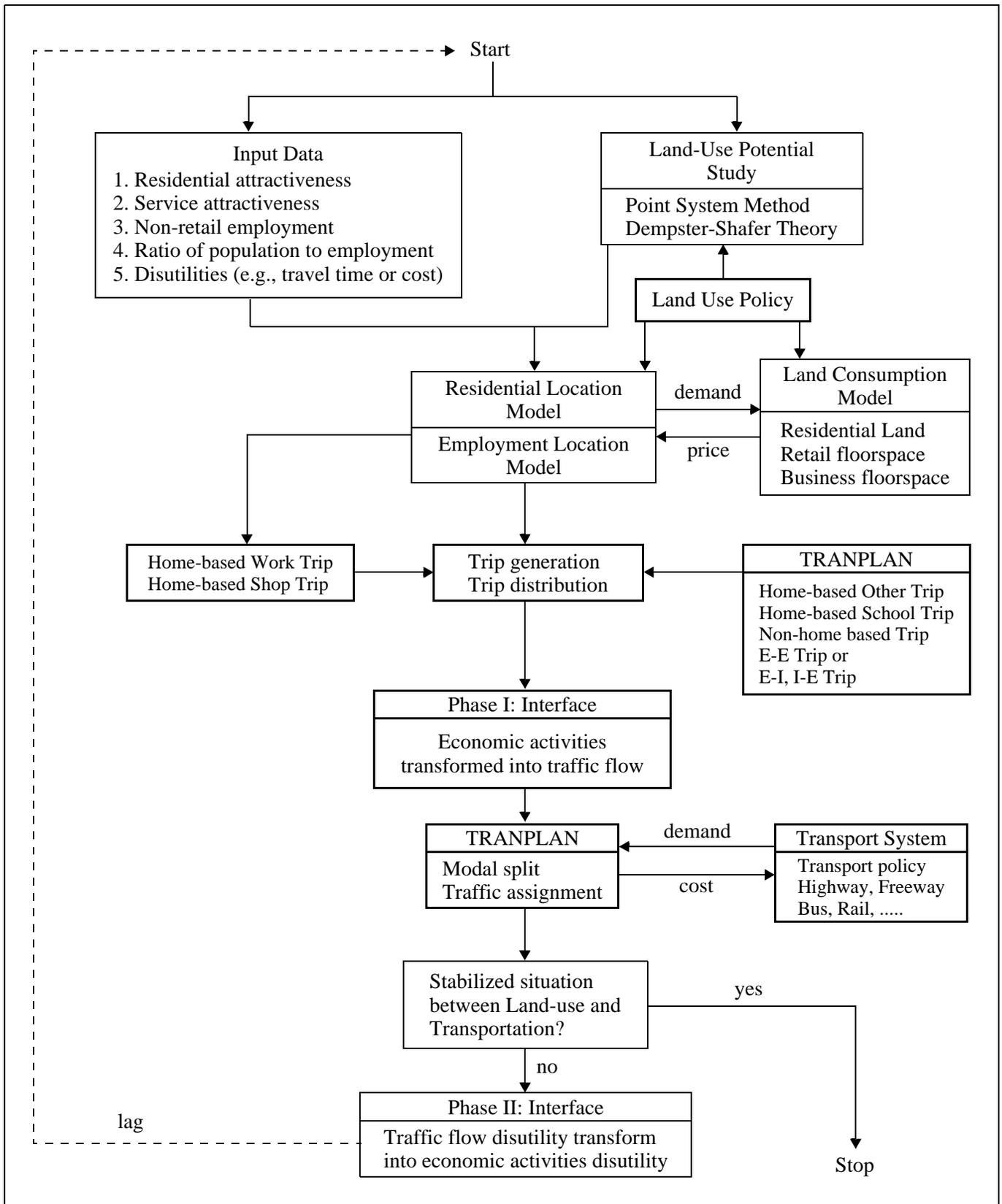


Figure 1: ITLUMS framework

3. *Interface Modules.* The Phase I Interface Module in Figure 1 translates the economic activities that result from the Land Use Allocation Module into input for the Travel Demand Module. The Phase II Interface Module facilitates the feedback from transportation back to land use. Phase II incorporates a time lag for the response of land use to changes in the transportation system.

The “flow” in Figure 1 is followed for a given time period until a stable solution is reached.

Land Use Potential Study

The land use allocation process begins with (a) projections for the expected population and employment for a given year and (b) information about the current and potential use of land in the study area. The study described here borrowed from a “point system” for assessing land use suitability that has been used by Lafayette, Indiana’s Area Plan Commission (APC). The Point System uses eight factors to determine how suitable a land area is for five land use types. The eight factors used in this study were soil productivity, soil stability for construction, flood plain status, degree of forestation, distance to utilities, distance to highways, distance to airport and railroad, and current land use. The five land use types are residential, industrial, commercial, agricultural, and open space. Using GIS and a simple FORTRAN code, the study automated the Point System calculations that the APC has done manually. In the process, an alternative to the Point System, based on Dempster-Shafer evidence theory, was also implemented.

The Point System and Dempster-Shafer land indexing methods offer different ways to assess the suitability of land for given uses. When the automated Point System method was applied to Lafayette area data, the resulting GIS plot of land use potentials closely resembled the long-range land use plan developed by APC with its conventional methods. When Dempster-Shafer was used, the plot was very much like APC’s phased land use plan. These results were very encouraging to both the APC participants in this study and to the researchers. While these two methods automate the land use potential study, there is a significant cost in terms of the data preparation required. It was decided in this study that land should be divided into 16 cells per square mile in rural areas and into 36 cells per square mile in urbanized parts of the study area. For each such cell in a study area of, say, 400 square miles, entering data on eight factors as they pertain to five land uses can lead to thousands of data entries. Fortunately, much of this information is becoming available in GIS-compatible format. For example, soil conditions and highway networks can be imported into GIS layers that allow automated determination of an individual cell’s soil and highway accessibility ratings. The land use potential study is a critical early step in the ITLUMS. It allows for a greater degree of consistency in seeking the appropriate uses of land in a community.

ITLUMS Model Calibration and Validation

Although the Lafayette study area had approximately 10,000 land use cells and 210 traffic analysis zones, experimentation showed that aggregating these units into the county’s thirteen townships provided the best basis for calibrating the model to historical data. Township data on population, housing units, and retail and non-retail employment for 1980, 1990, and 1993 were used to estimate ITLUMS parameters pertaining to trip lengths, dwelling units, rent, retail employment density, travel costs, etc. Calibrating the model for three different years indicated an adequate level of stability in the parameters, except where there were explainable trends in their values.

To validate the calibration results, the calibrated model was used to convert APC future-year values for demographic and economic values into land use patterns. Because ITLUMS incorporated expected transportation changes into its forecasts and the APC did not, a direct comparison of the forecasted land use patterns could not be made. However, the direction and magnitude of the differences between the ITLUMS and APC forecasts were deemed acceptable by the APC. In addition, ITLUMS would undergo further tests using scenarios of special interest to the APC, providing further opportunities to assess the value of ITLUMS as a planning tool.

Policy Tests

At the present time, northbound US Highway 231 enters downtown Lafayette from the south, turns west and crosses the Wabash River into West Lafayette and passes through the Purdue University campus. Currently under construction is a relocated alignment of US231 several miles to the west. No longer will through northbound traffic on US231 or traffic destined for Purdue have to travel through downtown Lafayette. Given the potential for increased accessibility from southern Tippecanoe County to Purdue, what will be the impacts on land use patterns in the county? The purpose of Policy Test 1 of ITLUMS was to answer this question. The results, according to ITLUMS, was an acceleration of growth in population and retail employment just south of Lafayette. In the City of Lafayette itself, population decline would continue more quickly, but retail employment would be helped. The transportation components of ITLUMS indicated the degree to which reduced congestion on old US231 permitted better travel times to activities in and near downtown Lafayette. Elsewhere, population and employment expected rates of growth were not significantly affected by the relocation of US231.

Just east of Lafayette, Interstate Highway 65 connects Indianapolis and Chicago. To the east of I65 is an area of rapid commercial and residential growth. A large new residential subdivision is planned for the south part of this growth area. Whereas Policy Test 1 looked at the land use impacts of a major change in the transportation system, Policy Test 2 reversed the nature of the question: What will be the impacts on the transportation system of a particular land use change, namely, the completion of a large new subdivision? The ITLUMS results quantified the degree to which levels of service on the road network east of I65 would be further degraded, and the benefits to be derived from additional capacity on SR26 and from an additional bridge across I65 to Lafayette.

The highway network change in Policy Test 1 involved a new road facility that ended at Purdue University. Beyond Purdue, existing roads would have to be used. What would be the impacts of extending the current US231 project beyond Purdue to the northwest quadrant of Tippecanoe County? This question became the basis for Policy Test 3. The results showed that few changes in land use would take place because of an extended US231 project. This is because other factors were more important than travel time in decisions that affect land use. Whereas the results of Policy Tests 1 and 2 showed a possible tendency for ITLUMS to be too sensitive to changing inputs, the results of Test 3 demonstrated that ITLUMS can take into account other factors in the land use decision process. While the results of Policy Test 3 were surprising to APC and the researchers, they were explainable and actually enhanced the credibility of the ITLUMS.

Conclusions

While the development of an Integrated Transportation Land Use Modeling System (ITLUMS) for Indiana MPOs has been largely successful, several concerns remain. The positive aspects of

ITLUMS are:

- It uses data available to Indiana MPOs.
- It automates several procedures that have been heretofore carried out manually with great tedium.
- The land use potential indexing methods encourage an objective and consistent approach to relating an area's characteristics to its best land use type(s).
- Its results were verified and endorsed by the participating MPO, whose data were used.
- It facilitates the analysis of alternate scenarios, increasing the planner's ability to anticipate problems associated with proposed development or transportation projects.
- Although ITUMS was developed using a full-scale GIS package (TransCAD), it was shown that ITLUMS can be implemented using Maptitude, a software package currently selling for about \$400.

The difficulties in using ITLUMS are:

- Manual entry of data for the land use cells can be extensive, unless the appropriate data are available in a format compatible with ITLUMS software.
- Determining appropriate land use suitability values, especially for the Dempster-Shafer method, requires practice.
- The Interface Modules in ITLUMS still involve manual tasks, such as editing output files from one module to produce input files for the next module.
- There may be a tendency for ITLUMS to exaggerate land use impacts of transportation changes, although Policy Test 3 demonstrates that this is probably not a serious problem.

The last stages of the ITLUMS project involve making implementation as convenient as possible. ITLUMS has already been demonstrated to interested Indiana MPOs, but the Interface Modules need to be automated and/or simplified. An implementation report in the form of a step-by-step user's manual is being prepared.

Note

This paper is based on the applications-oriented presentation made at the Sixth Transportation Planning Applications Conference in Dearborn, Michigan on 21 May 1997. A paper with a detailed description of the model has also been prepared. Later in 1997, the final report of the research report will be available from the Joint Transportation Research Program at Purdue University. The paper and/or the report can be obtained by contacting Prof. Fricker.

References

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